

Using tracker for jet energy correction

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- Calorimeter consists of two compartments and both has different response to electrons and hadrons
- Jets have both hadronic (charged and neutrals) and e/γ components.

Method description:

Jet energy=Response_charged+Response (e/γ)+Response (neutral)

- ◆ Change response of charged hadron of jet to energy from Tracker
- ◆ Add tracks out of reco cone (**A.Nikitenko**)

**Jet energy=E_TRACKER+Response (e/γ +neutral)_ECAL+
Response (neutral)_HCAL**


Response (R(ECAL), R(HCAL)) is calculated inside cone around jet axis using standard procedure and with default coefficients.

Expected response was calculated in different ways:


e/π technique (1), library of responses(2), matched cluster(3)

Remark: e/π technique, energy flow objects = matched cluster (D.Green)


Simplifications:

 **QCD dijet events with P_{t} 20–120 GeV are generated with PYTHIA 6.152 using parameters from jet production 2000.**

Only jet particles in cone 0.5 on generator level are propagated through cmsim 121.

 **The entry point of charged particles to ECAL was taken from generation on CMSIM level.**

No reconstruction algorithms in tracker were used

 **Parameters of algorithm:
(e/h)_{ECAL}, (e/h)_{HCAL}, $E_{\text{ECAL}}/E_{\text{HCAL}}$
for charged particles– used in algorithm were taken from test–beam data where HCAL was calibrated to electrons.**

$E_{\text{ECAL}}/E_{\text{HCAL}}$ depends on particle energy

Short description of procedure:

- ◆ Energy of charged hadrons of jet is taken from Tracker
- ◆ Summarized expected response of charged hadrons is subtracted from ECAL and HCAL

$$\text{Response (e/\gamma+neutral)}_{\text{ECAL}} = \text{Response}_{\text{ECAL}} - \text{Response(charged)}_{\text{ECAL}}$$

$$\text{Response (neutral)}_{\text{HCAL}} = \text{Response}_{\text{HCAL}} - \text{Response(charged)}_{\text{HCAL}}$$

$$\text{Jet energy} = E_{\text{TRACKER}} + \text{Response (e/\gamma+neutral)}_{\text{ECAL}} + \text{Response (neutral)}_{\text{HCAL}}$$

Expected response
calculation:

Version 1: e/ π technique

Version 2: library of responses

Version 3: matched cluster+(1 or 2)

- ◆ Charged particles out of reco cone were added

e/ π technique (Version 1)



For each interacted charged particle **Dan Green's procedure** to find **response of this particle in ECAL and HCAL** is used to calculate mean response in calorimeters.

For each charged the ratio of responses to electrons and pions is calculated:

$$e/\pi(\text{ECAL}) = e/h(\text{ECAL}) / (1 + (e/h(\text{ECAL}) - 1) * F0_ECAL)$$

$$e/\pi(\text{HCAL}) = e/h(\text{HCAL}) / (1 + (e/h(\text{HCAL}) - 1) * F0_HCAL)$$

$$F0_ECAL = 0.11 * \log(E_ECAL)$$

$$F0_HCAL = 0.11 * \log(E_HCAL)$$

F0_ECAL, HCAL – electromagnetic fraction of hadronic shower.

E_ECAL, E_HCAL – energy deposited in ECAL, HCAL **e/h** is obtained by fitting test-beam data.



For each charged particle **E3x3 around entry point** is used to determine if particle interacts in ECAL or not.

How deposited energy E_{ECAL} , E_{HCAL} are evaluated:

Particle interacted in ECAL

$$E_{ECAL} = 0.4 * E_{tracker} \text{ (test beam, talk of J.Freeman)}$$

$$E_{HCAL} = 0.6 * E_{tracker}$$

Particle does not interact in ECAL

$$E_{ECAL} = E_{MIP} \text{ (energy from EM cluster)}$$

$$E_{HCAL} = E_{tracker} - E_{MIP}$$

Response from charged particles is calculated.

Particle interacted in ECAL

$$R_{ECAL} = E_{ECAL} / (e/\pi)(ECAL)$$

$$R_{HCAL} = E_{HCAL} / (e/\pi)(HCAL)$$

$$e/h(ECAL) = 1.6$$

$$e/h(HCAL) = 1.39$$

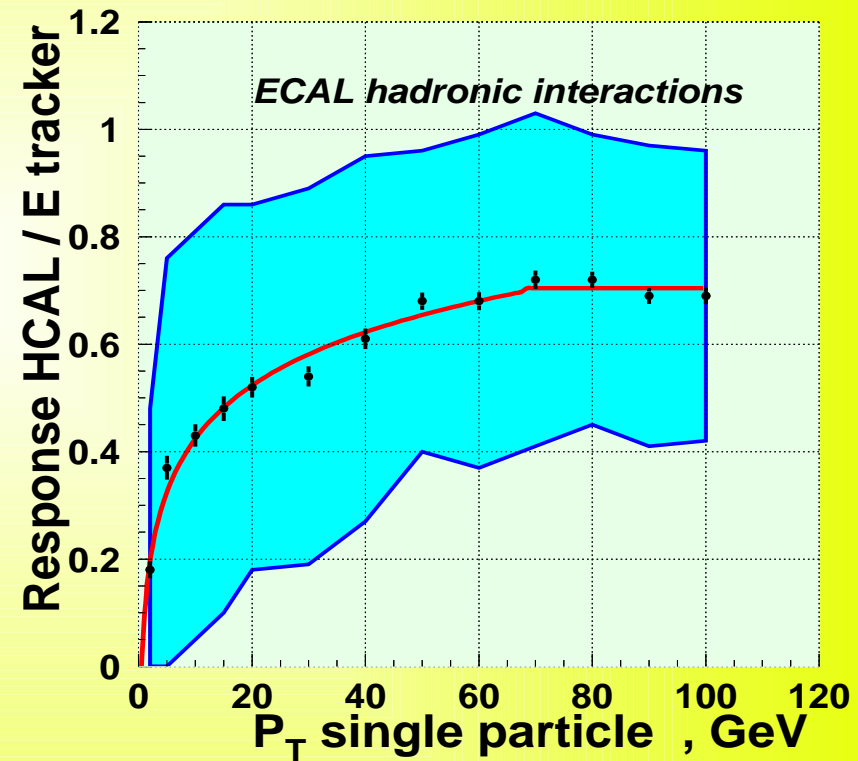
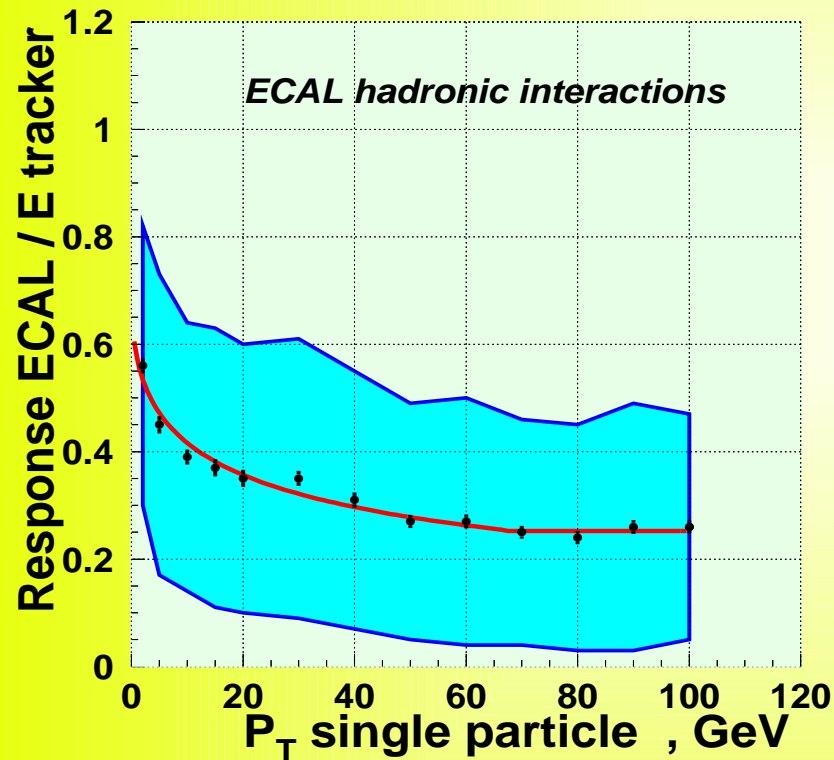
Particle does not interact in ECAL

$$R_{ECAL} = E_{MIP}$$





$$R_{HCAL} = E_{HCAL} / (e/\pi)(HCAL)$$

Library of responses (Version 2)

Mean responses were calculated using pion samples of different energies for the cases when pion is interacted in ECAL or not





Matched cluster+library of responses (Version3)

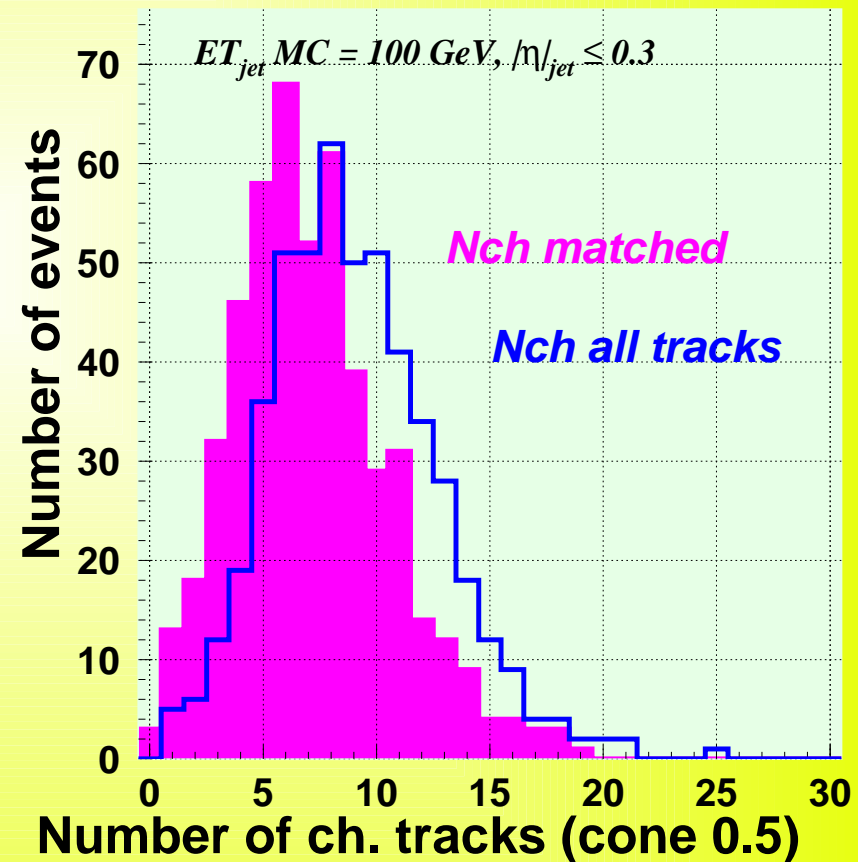
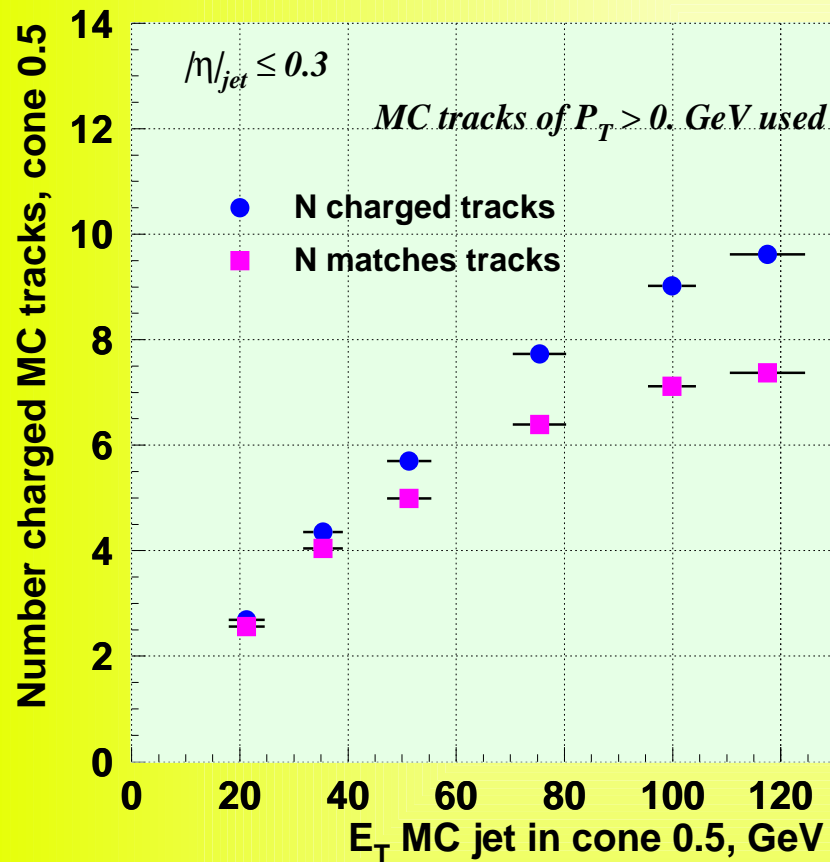
-  For each charged particle (in reco cone) 3x3 ECAL crystal matrix was constructed around entry point. Cluster building starts from maximal track.
-  For each charged particle (in reco cone) 3x3 HCAL tower matrix was constructed around entry point.
-  Energy response in ECAL+HCAL cluster (3x3 crystal+3x3 tower) was compared with Etracker for this particle
-  Energy of cluster matched with track was changed to the energy of particle in tracker.

Cluster is matched with track if: $-\sigma < E_{\text{tracker}} - E_{\text{cluster}} < 2\sigma$

$$\sigma / E = 100\% / \sqrt{E} \oplus 5\%$$

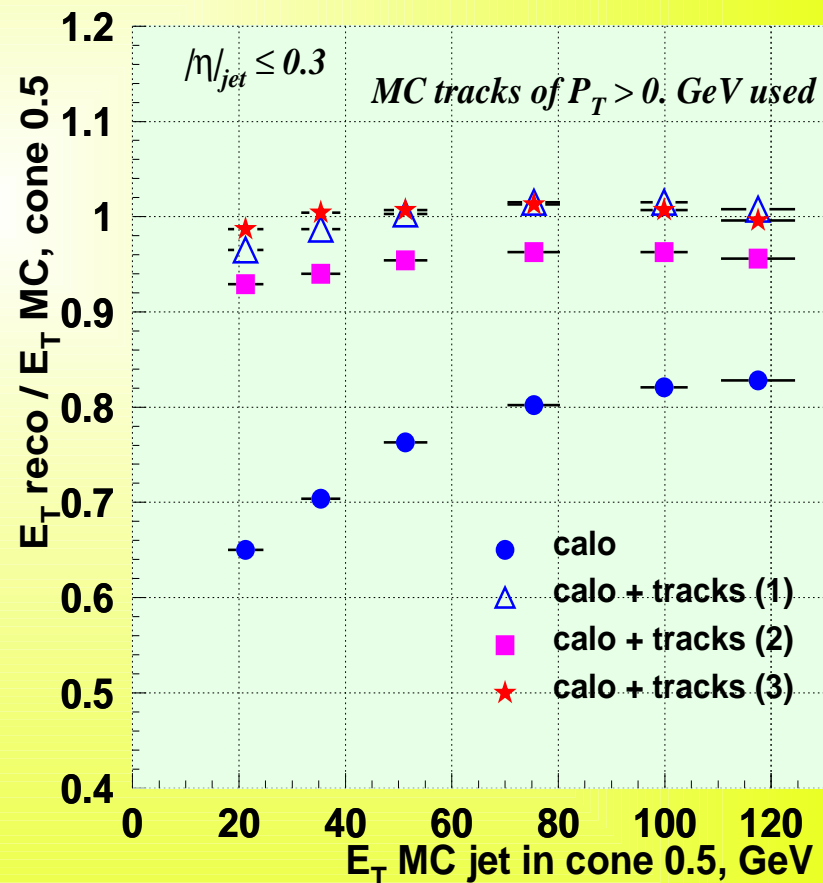
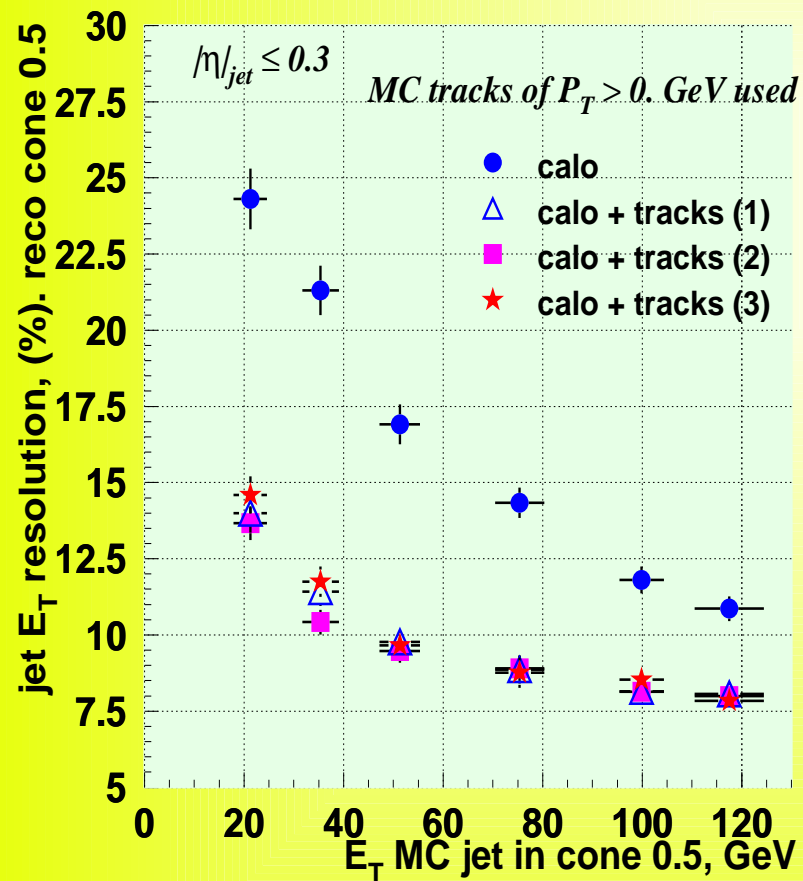
-  For tracks non-matched cluster expected response subtraction procedure was applied (1,2).
-  Charged particles out of reco cone were added

Mean number of all charged particles with hit within reco cone and mean number of particles matched with clusters for different jet energy (left figure). Distribution the number of all charged and charged matched with clusters for jet energy 100 GeV (right figure).



Resolution and mean ETrec/ETgen for different MC jet energy.

Window algorithm and algorithm with tracker information. Three options are used for calculating expected response: **e/ π technique (calo+tracks(1))**, **library of responses (calo+tracks (2))**, **matched clusters+library of responses (calo+tracks(3))**



Why for expected response subtraction $D(E_{\text{jet}}^{\text{rec}}/E_{\text{jet}}^{\text{gen}})/\langle E_{\text{jet}}^{\text{rec}}/E_{\text{jet}}^{\text{gen}} \rangle$

should be better:

Only calorimeter information:

$$E_{\text{jet}}^{\text{calo}} = \sum \text{Response}(e/\gamma) + \sum \text{Response}(\text{neutral}) + \sum \text{Response}(\text{charged})$$

$$D(E_{\text{jet}}^{\text{calo}}) = \sum D(\text{Response}(e/\gamma)) + \sum D(\text{Response}(\text{neutr})) + \sum D(\text{Response}(\text{char}))$$

Include Tracker information:

$$E_{\text{jet}}^{\text{tracker}} = \sum \text{Response}(e/\gamma) + \sum \text{Response}(\text{neutral}) + \sum \text{Response}(\text{charged}) - \\ - \sum \text{Response}(\text{charged})_{\text{teor}} + \sum E_{\text{tracker}} =$$

$$= E_{\text{jet}}^{\text{calo}} + \sum E_{\text{tracker}} - \sum \text{Response}(\text{charged})_{\text{teor}}$$

$$D(E_{\text{jet}}^{\text{tracker}}) = D(E_{\text{jet}}^{\text{calo}}) + \sum D(E_{\text{tracker}}) + \sum D(\text{Response}(\text{charged})_{\text{teor}}) = \\ = D(E_{\text{jet}}^{\text{calo}})$$

Statistical error is kept unchanged but mean energy become closer to it's value on generator level. But there is a systematical error connected with expected response calculations.

Minimization of systematical error can be made with $Z \rightarrow jj$ for example.

Summary

**We considered procedure of using tracker information :
change response of charged hadron of jet to energy from Tracker
Three options for response calculation were used:
*e/π technique (version 1), library of responses (version 2) ,
matched clusters+library of responses (version 3)***

**All versions gives the same improvement for energy resolution:
from 1.7 times at 20 GeV jets to 1.5 times for 100 GeV jets
for 20 GeV: from **24% to 14%**
for 100 GeV: from **12% to 8%****

***The best linearity is achieved with *version 3*:
matched clusters+library of responses+ tracks out of cone***

***However it is not excluded the possibility to have the same results with
two other options by tuning parametrizations.***